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A scrambling method for 10G Extended EPON upstream

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Outline

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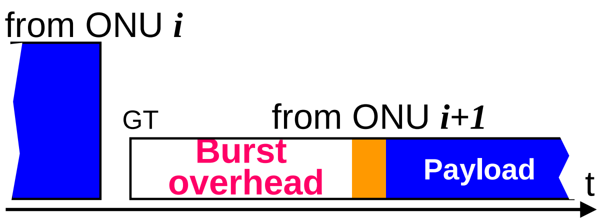
- Transmission Line coding
- Redundant Scrambler
  - Numerical simulation results
- Summary

Introduction

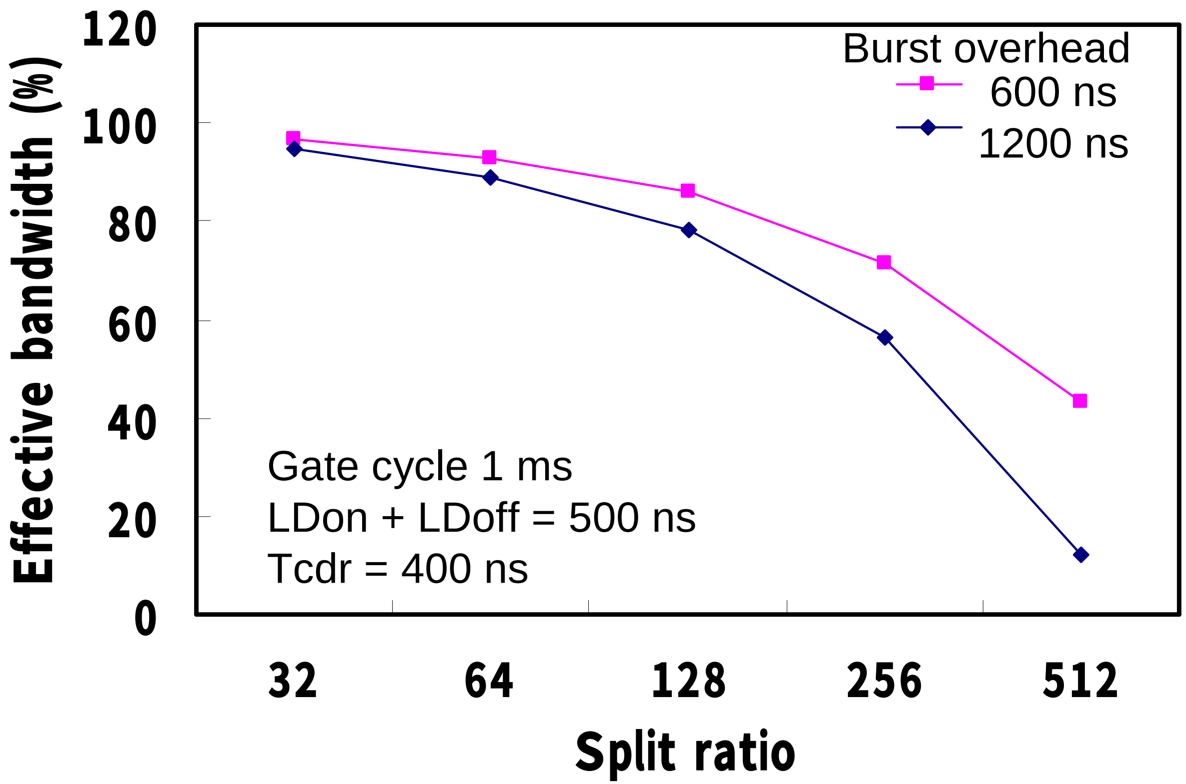
- Extended EPON targets are;
  - 1G-EPON with split ratio of >1:64 at a distance of > 20 km;
  - 10G-EPON with split ratio of > 1:64 at a distance of > 20 km;
- 10E-PON with high split ratio and short distance will be required
  - Subscribers in multiple dwelling units (MDUs)
  - Split ratio greater than 100 may be required.
  - Transmission bandwidth is shared by the users,

    Enhanced bandwidth efficiency is expected.
    - e.g. > 70%
- In order to enhance upstream bandwidth efficiency, burst overhead should be reduced.
  - Fast response Reset-less Rx
  - Balanced line coding
    - Smaller deflection of mark ratio than 64B66B
    - Reduced probability of long CID less than 66 bits



Upstream bandwidth efficiency

Burst Overhead	Split ratio		
	64	128	256
1200 ns ($T_{rec\_settling}$ 800 ns)	**89.0 %**	**78.1 %**	**56.2 %**
600 ns ($T_{rec\_settling}$ 200 ns)	**92.9 %**	**85.8 %**	**71.5 %**



Transmission line coding

Desired features of line coding

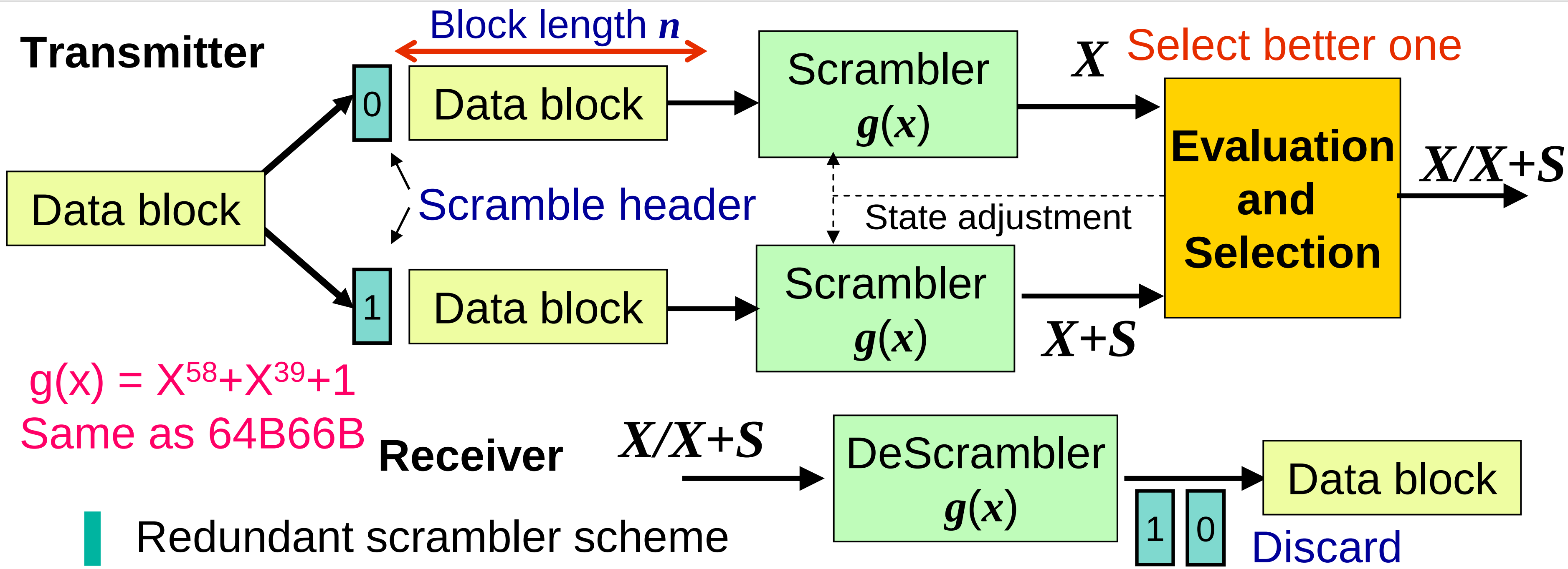
- Small deflection of mark ratio and reduced probability of long CID
- Small redundancy and small complexity
- Without error propagation in decoding.

	Scrambled NRZ	64B66B	8B10B	Redundant Scrambling (block length n)
Mark-ratio deflection	Large	Large	**Small**	**Small**
Rate increasing ratio	**1**	1.03125	1.25	$n/(n-1)$ **1.0158 for $n = 64$**
Prob. that CID of large len. L occur in a block of len. n	$n \cdot 2 \cdot 2^{-L}$	$n \cdot 2 \cdot 2^{-L}$	**(Max. L < 6)**	$(n \cdot 2 \cdot 2^{-L})^2$

- 8B10B code has excellent performance of mark ratio and CID, however, the rate increasing is as large as 1.25 and transmission efficiency degrades.

We proposed "New Redundant Scrambling"

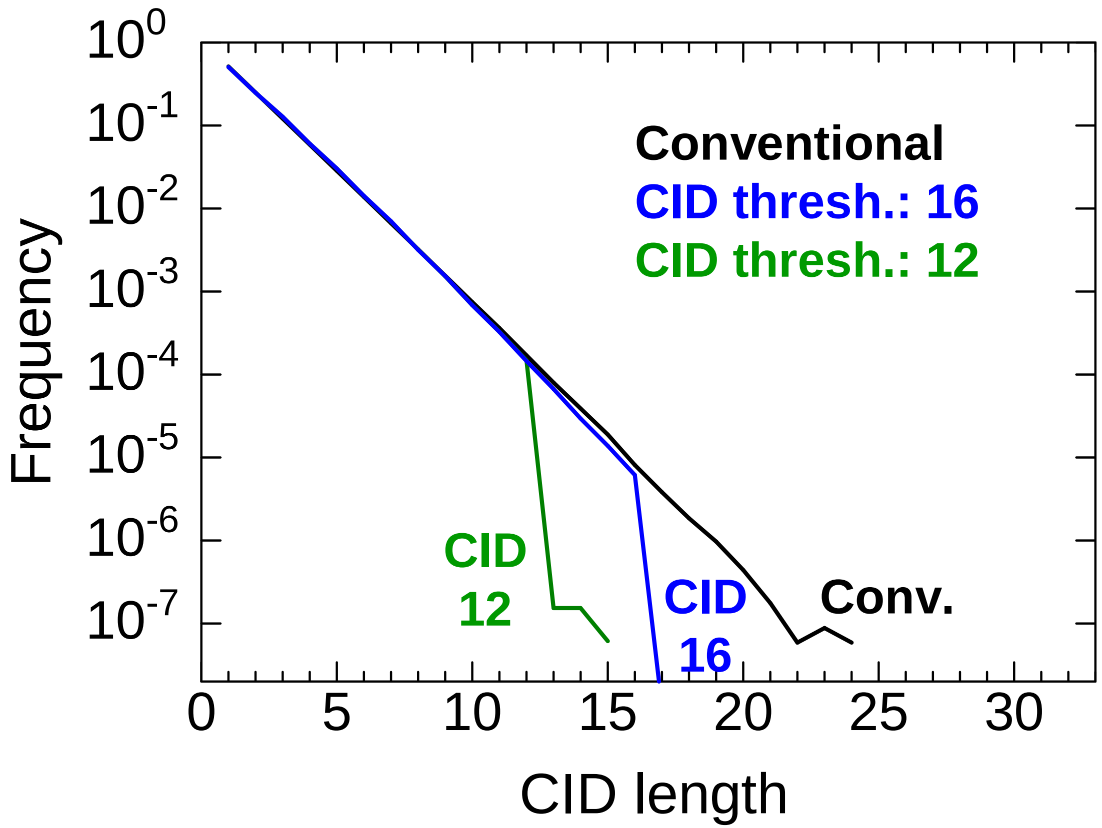
Redundant scrambling scheme



- Redundant scrambler scheme
  1. Transmission data frame is fed into two scramblers
  2. Scrambling is applied by frame by frame
  3. Maximum CID length and/or mark ratio of the two scrambled frames is evaluated
  4. The better scrambled frame is selected
  5. A redundant bit is placed in the head of a frame to indicate the selection.
  6. At the Rx, the sequence is descrambled with the scrambler and header bits are discarded

Advantage of the redundant scrambling (1) -CID length-

- Verification through numerical simulation
  - Block length = 64
  - Scrambler (self-synch.): $g(x) = x^{21} + x^{19} + 1$



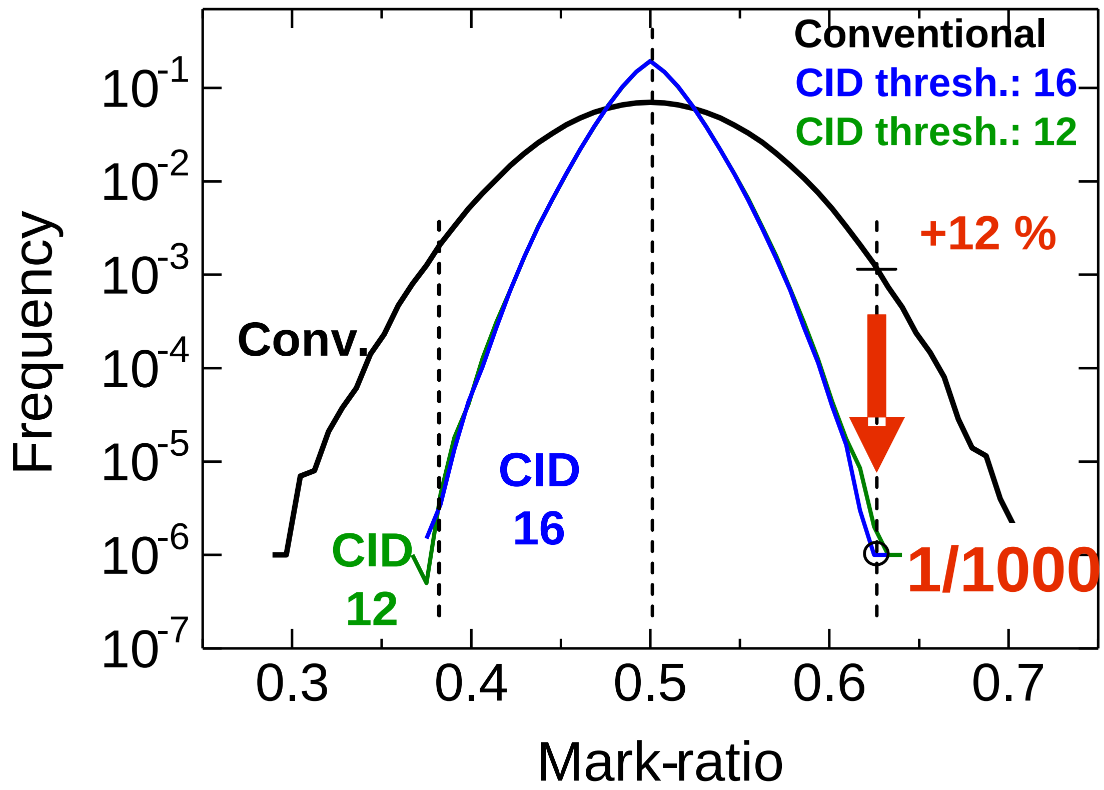
The CID lengths are suppressed by the threshold level.

Advantage of the redundant scrambling (2) -mark ratio-

Verification through numerical simulation

- Block length = 64
- Scrambler (self-synch.): $g(x) = x^{21} + x^{19} + 1$

Distributions of deflective mark-rate frequency for consecutive L = 4 frames



Mark-ratio deflection is reduced to 1/1000 for +/-12% deflection

Summary

- Redundant scrambling was proposed.
  - Simple architecture, low redundancy
  - Improvement in burst transmission performance was confirmed.
    - Reducing baseline deflection to 1/1000 with 3% redundancy.
    - BER characteristic was improved.
    - Scrambling function can be set as same as 64B66B
- The redundant scrambler is an attractive candidate for 10G upstream line code to enhance bandwidth efficiency.